

CLUST - EVAP Monte Carlo Simulation Applications for Determining Effective Energy Deposition in Silicon by High Energy Protons

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Abstract

The CLUST-EVAP is a Monte Carlo simulation of the interaction of high energy (25 – 400 MeV) protons with silicon nuclei. The initial nuclear cascade stage is modeled using the CLUST model developed by Indiana University over 30 years ago. The second stage, in which the excited nucleus evaporates particles in random directions, is modeled according to the evaporation algorithm provided by H. H. K. Tang of IBM.

Using the CLUST-EVAP code to model fragment production and the Vavilov-Landau theory to model fluctuations in direct ionization in thin silicon layers, we have predicted energy deposition in silicon components for various geometrical configurations. We have compared actual measurements with model predictions for geometry's such as single, thin silicon particle detectors, telescopic particle detectors flown in space to measure the environment, and thin sensitive volumes of modern micro-electronic components.

We have recently compared the model predictions with actual measurements made by the DOSTEL spectrometer flown in the Shuttle payload bay on STS-84. The model faithfully reproduces the features and aids in interpretation of flight results of this instrument.

We have also applied the CLUST-EVAP model to determine energy deposition in the thin sensitive volumes of modern micro-electronic components. We have accessed the ability of high energy (200 MeV) protons to induce latch-up in certain devices that are known to latch-up in heavy ion environments. However, some devices are not nearly as susceptible to proton induced latch-up as expected according to their measured heavy ion latch-up cross sections. The discrepancy is believed to be caused by the limited range of the proton-silicon interaction fragments. The CLUST-EVAP model was used to determine a distribution of these fragments and their range and this is compared to knowledge of the ranges required based on the known device structure. This information is especially useful in accessing the risk to on-orbit performance in a heavy ion environment based on testing performed with only protons.



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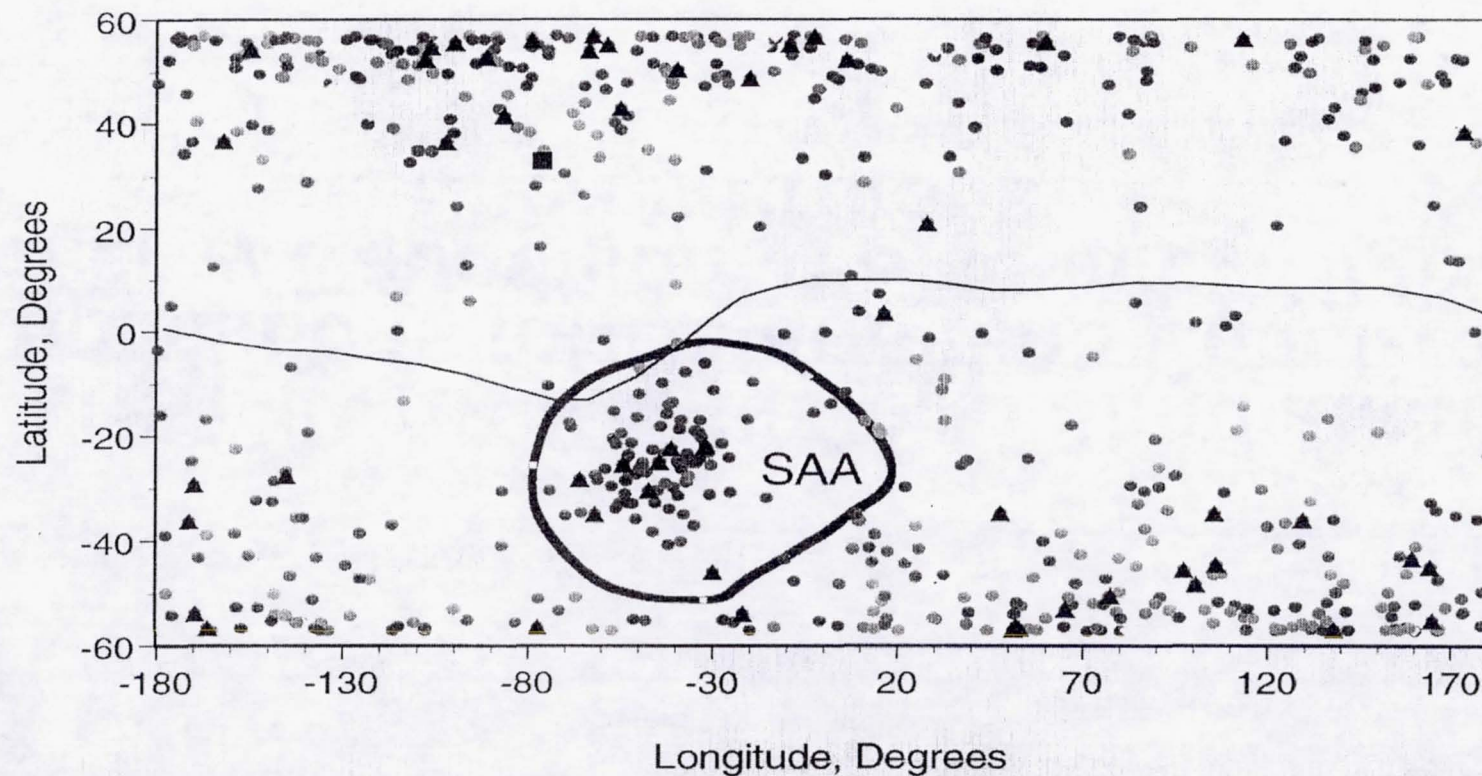
Actual Space Shuttle GPC SEU'S

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02/29/00

57 Degree Inclination Single Event Upsets





*Single Event Effect (SEE)
Testing - OPTIONS*

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- **High Energy Protons - screen**
 - expose system (2.5" proton beam) while operating in air
 - observe SEE's (from outside cave)
 - predict onorbit SAA SEE rates
 - predict onorbit GCR SEE rates and establish upper bound to GCR failure rate (for failures not observed with protons)

- **Low Energy Heavy Ions - complex test**
 - expose de-lidded chip operating in vacuum
 - observe SEE's (from outside chamber)
 - accurate prediction of on-orbit failures including all failure modes



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*Testing Options - proton
vs. heavy ion*

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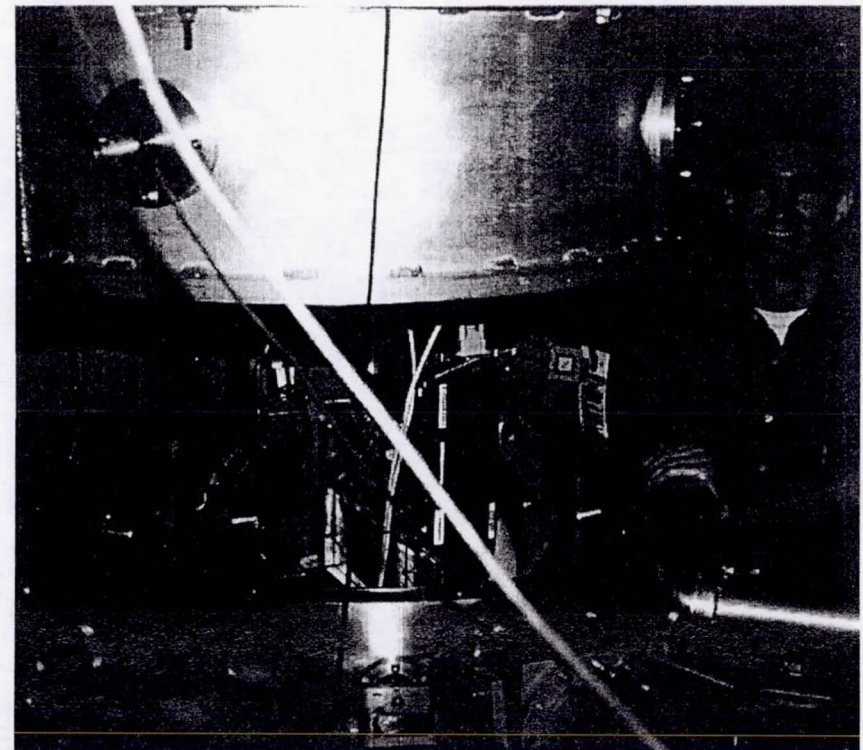
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Proton Cave



Heavy Ion Vacuum Chamber



*Total Dose Testing**EA44/Station Engineering Office**Pat O'Neill**02/29/00*

- Dose Requirement depends on mission and shielding
 - Shuttle - no requirement
 - Station requires dose times 2 (for environment) times 2 (for lot-to-lot variation) times 10 years:

E.g. for shielding of 3000 mils aluminum, part must be good after test of:

$$12.95^* \text{ rad(si)/year} \times 10 \text{ year} \times 4 = 518 \text{ rad(si)}$$

- Proton test of 10^{10} protons/cm² provides 600 rad(si)
- Always provide at least 250 mils to stop the electron background

* SSP30512



*Ionizing Radiation
Requirements*

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“... shall meet performance and operability requirements while operating within the natural radiation environment as specified in ...”

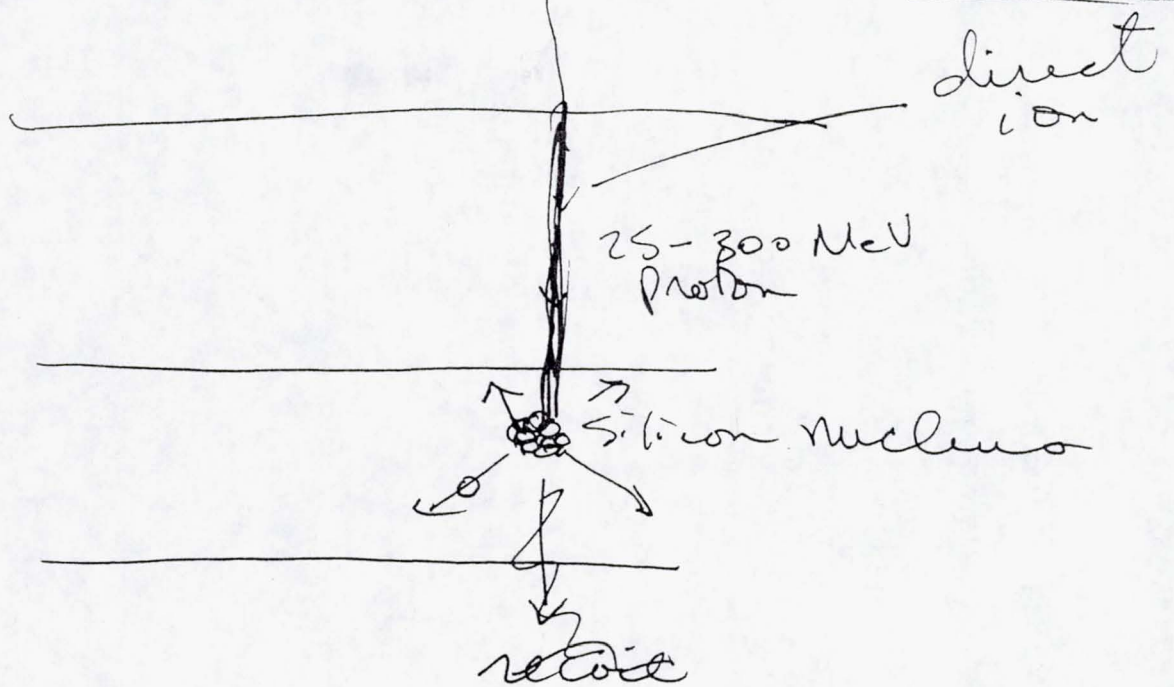
SHUTTLE

- NSTS 07700 Volume X Book 1 & 2
- Flux vs. LET for 57 degree x 500 km orbit, solar minimum, 0.1” shielding
- Single Event Effect only

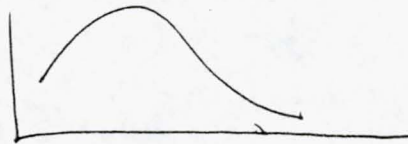
SPACE STATION - SSP30512 Rev. C Space Station Ionizing Radiation Design Environment

- Flux vs. LET for 51.6 degree x 500 km orbit, 0.05” shielding or actual shielding
- Single Event Effect and Total Dose

ENERGY DEPOSITION IN THIN SLABS



Model: $\frac{DE}{V}$ Vavilov - Landau

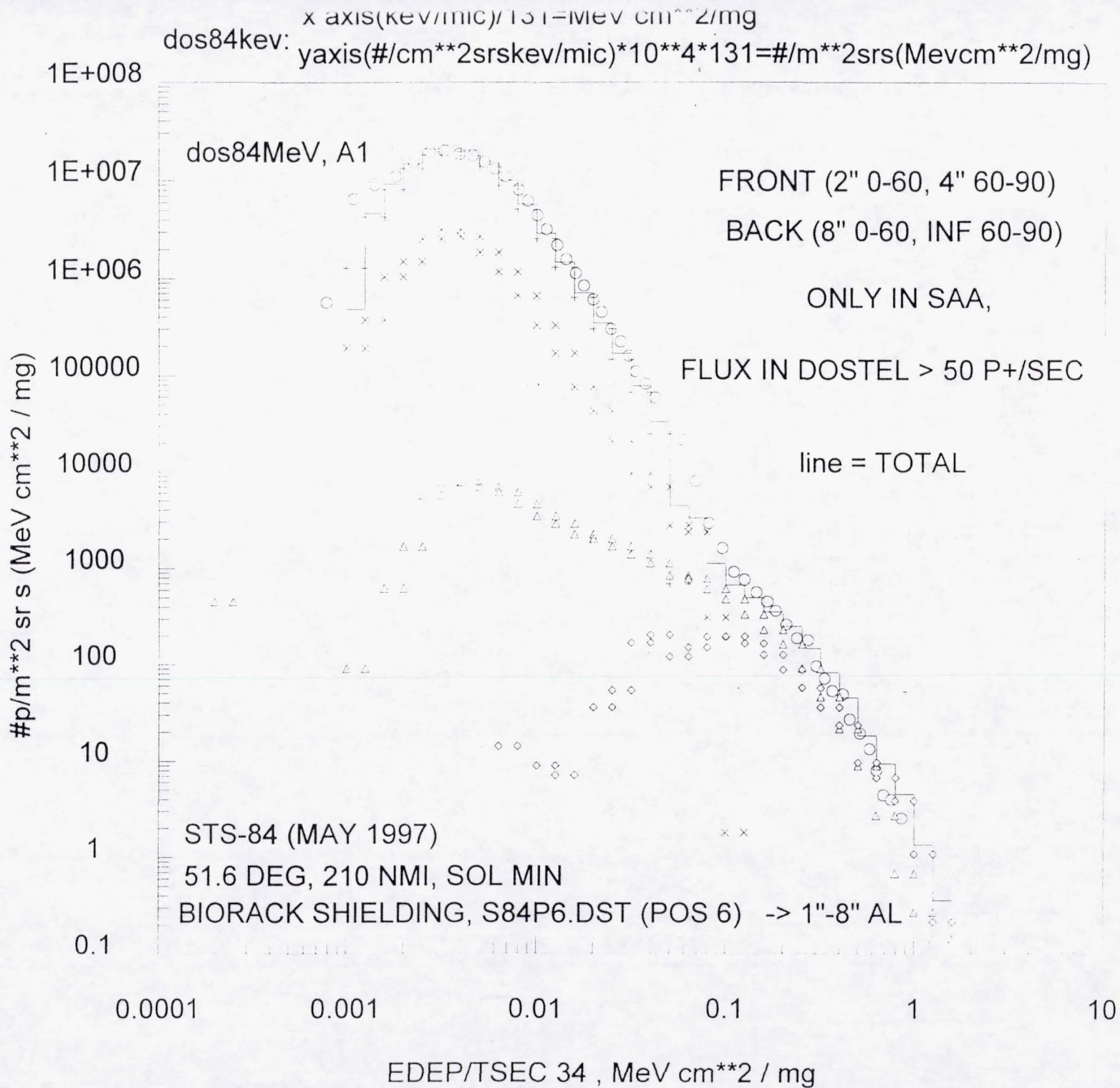


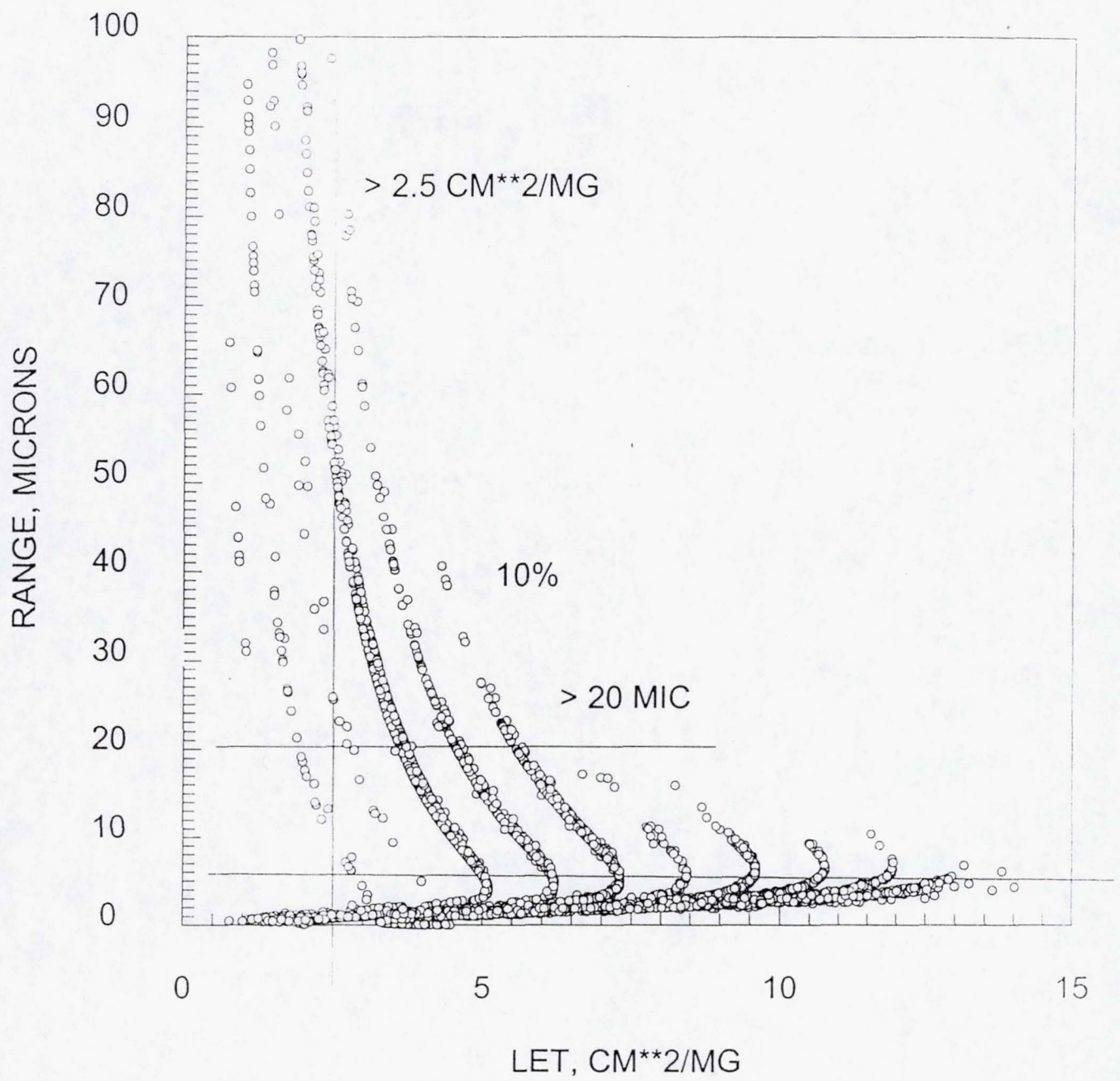
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Nuclea Cascade - CLUST
Evaporation - Tang's

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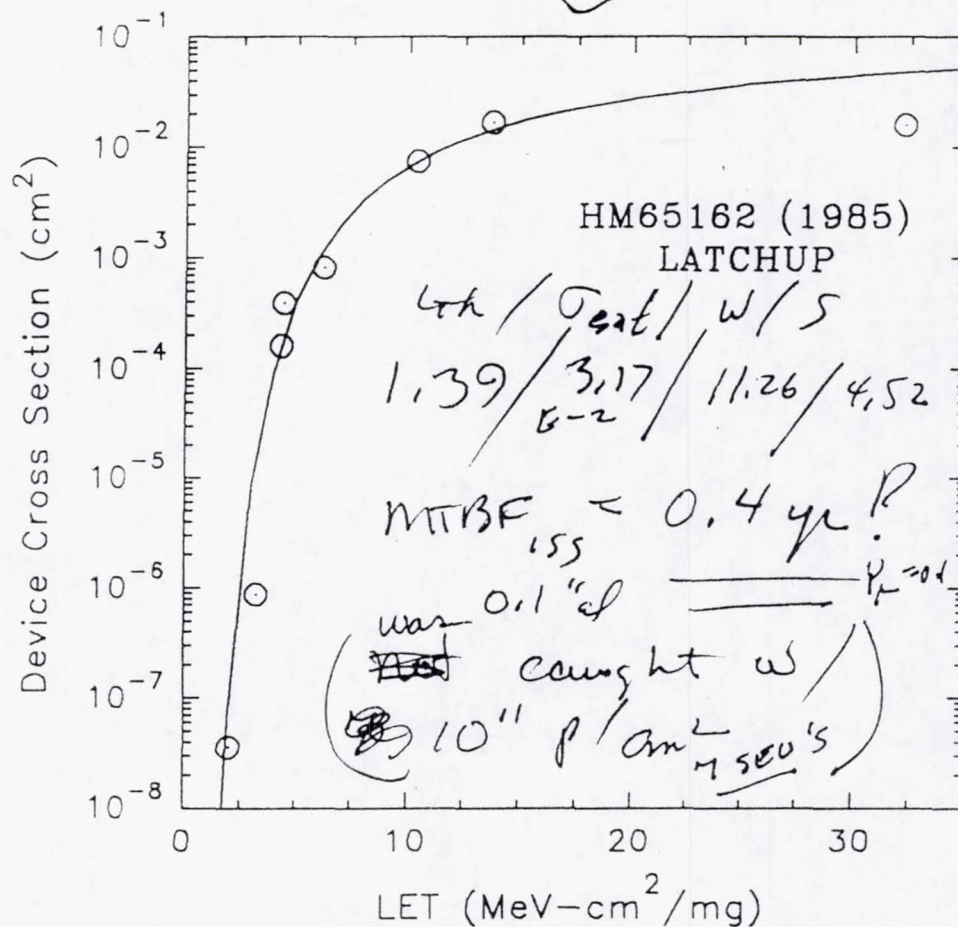


Fig. 1: Heavy-ion SEL cross section for the HM65162 SRAM produced in 1985. Data (points) are from Levinson *et al.* [4]. The curve is from (6) using $\sigma_0=0.116 \text{ cm}^2$, $L_{1/e}=28.3 \text{ MeV-cm}^2/\text{mg}$.

$$t = 0.1$$

$$t = 178 \mu (16 \text{ bit})$$

Device - 2

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